Chapter 7

Chapter 8
SUMMARY, FINDINGS AND RECOMMENDATIONS

8.1 SUMMARY OF INVESTIGATION

Under the authority of the National Construction Safety Team Act, a team was formed by the NIST Director on Feb. 27, 2003 to investigate the failure seven days earlier of The Station nightclub in West Warwick, Rhode Island. The objectives of the investigation were the following:

- to establish the likely technical cause or causes of the building failure;
- to evaluate the technical aspects of evacuation and emergency response procedures;
- to recommend, as necessary, specific improvements to building standards, codes, and practices based on the findings made pursuant to the duties listed above; and
- to recommend any research and other appropriate actions needed to improve the structural safety of buildings, and improve evacuation and emergency response procedures, based upon the findings of the investigation.

The following activities were undertaken by the team to reach the first two objectives and to establish the basis for the remaining two:

- identification of technical issues and hypotheses requiring investigation through consultations with experts in fire protection engineering, emergency evacuation, and members of other teams investigating The Station fire;
- data collection from local authorities, contractors and suppliers, building and fire protection design documents, records, plans, and specifications, video and photographic data, telephone and radio transmissions, field data, a limited number of interviews and other oral and written accounts from building occupants and emergency responders, and other witnesses as reported by the news media;
- analysis and comparison of national model building and fire codes and practices, as well as review and analysis of practices used in operation of the building;
- simulation and analysis of phenomena (with associated uncertainties), including fire spread, smoke movement, tenability, occupant behavior and response, evacuation issues, and operation of active and passive fire protection systems; and
- testing to provide additional data and validate computer simulation predictions.

The previous seven chapters of this final report describe the methodology used to conduct the investigation, detail what occurred on the night of Feb. 20, 2003, review the history of the building and the model codes and standards that would have applied to a building of this type, and present the results of testing and simulations. The key findings from the investigation are summarized in the following section. Recommendations for improving model building and fire standards, as well as codes, and practices are listed in Section 8.3; Section 8.4 describes actions already taken by local authorities and code making organizations. Research recommendations and other appropriate actions are provided in Section 8.5.

8.2 FINDINGS

During the course of the investigation NIST examined the life safety systems that were part of the building design; the materials used as part of the structure, as finish products and as building contents; the egress process; the response of the fire department to the incident; and relevant model building and fire codes. NIST developed new information or confirmed published reports as to the initiating event, the reasons for the very rapid spread of fire and smoke, the difficulties encountered by the occupants during egress, and the mass casualty situation confronted by the fire department. Many of the findings summarized in this section had a direct bearing on the tragic outcome of this specific event; others had a peripheral role but are important to capture because of the potential to positively influence the outcome of future events. All findings are presented in various categories below, with the key findings highlighted in bold.

8.2.1 Materials

- **A non-fire retarded foam sample purchased by NIST ignited within 10 seconds when exposed to a pyrotechnic device (15x15 gerb) in an arrangement similar to the set up on the platform of the nightclub. When a plywood panel with fire retarded polyurethane foam was exposed in a similar manner to a 15 x 15 gerb, no ignition of the panel occurred, nor did the plywood ignite with no foam present.**
- **As could be seen in the WPRI video, flames spread rapidly over the foam in the nightclub, generating smoke and enough heat (calculated to be almost 60 MW at its peak) to ignite the wood paneling underneath and adjacent to the foam. The wood paneling in the nightclub was estimated to contain over 95 % of the fuel load, so that once most of the foam was consumed (estimated to be around two minutes after ignition of the foam), the fire transitioned to a wood frame building fire, with a steady heat release rate calculated to be around 45 MW.**
- **There was no fire resistant barrier between the interior of the nightclub and foam thermal insulation which had been installed in the stud space on the interior side of external walls of the drummer's alcove.**
- **In the reconstruction of the *platform area fire* conducted at NIST, within 90 seconds after ignition of the non-fire retarded polyurethane foam conditions near the middle of the dance floor at head height (1.5 m, or 5 ft, above the floor) were lethal. (Temperature exceeded 460 ^{o}C (860 ^{o}F), carbon monoxide volume fractions reached 1 percent, hydrogen cyanide levels exceeded 0.07 percent, oxygen volume fraction fell to 9 percent, and radiant heat flux exceeded 40 kW/m^2.)**
- **NIST could not obtain samples of the foam that actually had been applied to the nightclub walls to conduct a chemical analysis to determine if the polyurethane material contained fire retardants; however, the ignition behavior of the foam exhibited on the WPRI video was consistent with the behavior observed in the NIST testing with a non-fire retardant foam.**
- Model codes require that foamed plastic material used as an interior finish pass large-scale fire tests that substantiate the combustibility characteristics of the material related to the actual end use.

- Model codes permit the use of pyrotechnic devices in nightclubs if certain precautions are taken and with the approval of the authority having jurisdiction.
- The average heat flux from the gerbs purchased by NIST impinging on a surface was determined to be much less than the average heat flux from the fire to the foam surface, once ignition of the foam had occurred.
- The heat release rate from foam samples found at the site and representative materials purchased by NIST ranged between about 250 kW/m^2 and 1100 kW/m^2 when exposed to radiant fluxes between 20 kW/m^2 and 70 kW/m^2 in a cone calorimeter.
- The carpet and furnishings contributed a relatively small amount to the fire, and the ceiling tiles a negligible amount.

8.2.2 Fire Protection Systems

- **Experiments conducted at NIST in a reconstruction of *the platform area* fire demonstrated that a water sprinkler system installed in the test room in accordance with NFPA 13 [1] was able to control the fire initiated in non fire retarded polyurethane foam panels and maintain tenable (survivable) conditions at head height in the test room for the duration (over five minutes) of the experiment. This was in contrast to the reconstruction of the platform area fire with no sprinklers present, which led to likely fatal conditions at head height in the test room in about 1-1/2 minutes. A computer simulation of the full nightclub with and without sprinklers led to a similar positive result for the sprinklered scenario.**
- **Automatic fire sprinklers were not installed in The Station nightclub, nor were they required for such existing structures under the 2003 editions of the model codes.**
- **A heat detection/fire alarm system was installed in The Station nightclub, which activated (sound and light strobe) 41 seconds after ignition of the polyurethane foam, by which time the crowd had already begun to move toward the exits.**
- Several hand-held fire extinguishers were located on the premises, at least one of which was used in an attempt to extinguish the fire on the platform.
- Standard exit signs were located above each exit.
- The building was equipped with emergency egress lighting.
- The kitchen was equipped with a dry powder fire suppression system above the stove.

8.2.3 Occupant Load and Egress

- **The first patrons recognized the fire danger about 24 seconds after ignition of the foam; the bulk of the crowd began to evacuate shortly after that, around the time the band stopped playing (30 seconds).**
- **The rate of egress from the main entrance at the front of the building was limited by the single doorway inside the vestibule, not the double doors visible from the outside.**
- **About 2/3 of the occupants appear to have attempted to leave through the single main entrance in the front of the building; many were unsuccessful.**

- **Prior to 1-1/2 minutes into the fire, a crowd-crush occurred in the front vestibule which almost entirely disrupted the flow through the front exit. The precise event which led to the crowd-crush likely was related to the arrangement of the single interior door with merging streams of traffic and the pressure to escape the rapidly deteriorating conditions in the main area of the nightclub.**
- **Measurements of temperature, heat flux and gas species in a reconstruction of the platform area fire at NIST and computer models of the NIST experiment and the full nightclub suggest that the conditions around the platform, dance floor, sunroom, and dart room would have led to severe incapacitation or death within about 1-1/2 minutes after ignition of the foam for anyone remaining standing, and for not much longer even close to the floor.**
- **The number of building occupants at the time of the fire was reported by the Providence Journal to be 440 [2].**
- The Station had three doors suitable for exit by occupants.
- The main area of the nightclub around the platform was open with very few chairs, stools or tables, consistent with a festival seating arrangement. Based upon the arrangement, the geometry of the exits, and the floor area, the occupant limit for a similar building would be 420 persons according to both NFPA 5000 [3] and the International Building Code [4].
- For more than a minute into the fire, the crowd moved in an orderly fashion at an egress rate estimated to be a bit faster than 1 person/second through the main entrance of the building.
- It was reported by the Providence Journal that a little over half of all people who successfully escaped via the doors (main entrance plus main bar plus kitchen plus platform door) exited via the main entrance.
- The windows in the main bar room and the sunroom became the secondary routes of escape once the main entrance became impassible, and, according to reports, they accounted for over 1/3 of the successful evacuations.
- The high number of victims found relatively close to the windows in the sunroom suggests that the environment became untenable more quickly than the victims were able to find a secondary route (e.g., through the sunroom windows) once the platform door and main entrance became unusable.
- The small number of victims found in the main bar room suggests that the main bar room exit door and windows provided open routes of escape up to the point where conditions in that area of the building became untenable.
- A computer model of The Station nightclub fire suggests that the conditions in the main bar area near the floor may have been survivable for more than three minutes after ignition, which is consistent with the WPRI video that showed people being assisted through the main bar windows up to 4 minutes after the start of the fire.
- A significant number of victims were found in the dart room, storage area, and office near the back of the building, suggesting that they (i) were unfamiliar with the building and hoped to find a safe exit in that region, (ii) did not realize that an exit existed inside the kitchen, or (iii) became disoriented while heading for the side exit of the main bar room.

- An interior door which opened inward was located at the platform exit, but the orientation of the door did not play a role in delaying the evacuation process since the rapid fire growth in that vicinity discouraged patrons from attempting to escape via the platform door exit.
- A preexisting exit adjacent to the lavatories at the back of the structure had been eliminated during some previous construction.
- The Team found no evidence of a written emergency action plan, a written fire prevention plan, or employee training to assist safe and orderly evacuation.
- No evidence was found that a uniformed firefighter was on the premises at the start of the fire; however, at least two off-duty West Warwick police officers were present, including one who called in the fire from within the building.

8.2.4 Emergency Response

- The first 911 call reporting a fire was before 11:09 pm, less than 40 seconds after ignition of the foam.
- **West Warwick police officers on the scene reported the fire about one minute after ignition of the foam, leading to the dispatch of four engines with six fire fighters and three fire officers, a tower-ladder truck with two fire fighters, a rescue unit with two attendants, and a battalion chief.**
- **The first fire engine, staffed with one firefighter and a fire officer, was confirmed on-scene less than five minutes after the first 911 call was received, which was well within the limits of the NFPA standard [5] that states the fire department should be able to respond to a call within six minutes at least 90 percent of the time.**
- NFPA standards [5] recommend a minimum staffing level of four firefighters on both engine and truck companies, which was not achieved. Additional firefighters on scene at the crucial initial phase of the response would have benefited the rescue and firefighting efforts, although NIST is unable to say how the outcome might have been altered.
- Rhode Island's fire/rescue, emergency medical services and law enforcement agencies were confronted with the largest life loss fire incident in the State's history.
- Mutual aid agreements with neighboring jurisdictions were effective in bringing the necessary resources (equipment and emergency responders) to the scene of the incident.
- A mass casualty plan was implemented capably within about 10 minutes of arrival of the first engine on the scene, such that within two hours of the start of the fire, all occupants needing medical attention had been evacuated from the scene and transported to medical facilities.
- Because of the ongoing criminal investigation, the medical examiner's reports that may have revealed the likely causes of death of the 100 victims of the fire were not available to NIST.
- Communications challenges resulting from limited radio equipment capabilities and the high volume of traffic substantially hampered the Incident Command's effective coordination of fire ground and triage operations, as well as the routing of responding EMS units to area hospitals.

8.2.5 Public Building Record-keeping Practices

- Records were not found of the initial building design. Records of modifications -- when located -- lacked sufficient detail to track the changes to the structure.
- Neither the historical nor most current use and occupancy permit for the building was located; however, the use of The Station was consistent with the IBC and NFPA 5000 occupancy classifications of "Group A-2" and "Assembly," respectively.
- The main deficiencies of the building identified during the history of inspections by the Town of West Warwick related to the location of the fire extinguishers, non-functioning exit signs and emergency lights, broken panic hardware on an exit door, and the direction of swing of an exit door.
- On numerous reports, deficiencies identified by the inspectors were later annotated as "OK," but with no official re-inspection signature.
- No Town of West Warwick or State of Rhode Island documents prior to Feb. 20, 2003 were located that mentioned foam materials on the walls of the nightclub, nor the use of pyrotechnics similar to those used on Feb. 20, 2003.

8.2.6 Referenced Codes and Standards

Tables 8-1, 8-2, and 8-3 list, respectively, the model codes and standards in the areas of materials, fire protection systems, and occupant load and egress that relate to the findings of the NIST investigation team. Table 8-4 summarizes the issues surrounding applications of the code, and building and fire safety practices. References are to the appropriate sections/paragraphs in the current International Building Code [4], the Life Safety Code [7], NFPA 5000 [3], and the standards contained therein. (The relevant sections in the International Fire Code and the Uniform Fire Code can be linked to the corresponding sections in the International Building Code and NFPA 5000 through the Tables provided in Appendix K.) The last column indicates the relevance of the issue to the outcome on Feb. 20, 2003. Based upon the computer simulations and other findings from the investigation, an "H" was assigned to issues that, properly addressed, were highly relevant and would almost certainly have reduced substantially the loss of life (these are also highlighted in bold); an "L" implies a low likelihood that addressing the issue would have reduced the loss of life for this particular incident; and "M" implies moderate relevance to the specifics of this particular incident. Consideration by the model code organizations and the building and fire safety professions for those actions marked as "L," while not linked tightly to the outcome of The Station fire, is still warranted. In some cases, actions may be called for that are not even addressed in the model codes as currently written; the code sections identified in Tables 8-1 through 8-4 are not meant to be inclusive.

Table 8-1 Findings Concerning Materials Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Polyurethane foam used as sound insulation on platform and walls. Foam thermal insulation unprotected in back platform wall.	**ASTM E84 [9]**	**X**		
	NFPA 255 [11]	**X**		
	NFPA 286 [10]		**X**	
	IBC:2604 [4]		**X**	
	5000:10.4.3.1 [3]		**X**	
Pyrotechnic devices were used as part of the theatrics. **Little guidance provided to AHJ* regarding appropriate use of pyrotechnics.**	**NFPA 1126 [12]**	**X**		
Unknown fire rating on wood paneling.	IBC:803.6 [4]			X
	5000:16.3.3.3 [3]			X

* Authority Having Jurisdiction

Table 8-2 Findings Concerning Fire Protection Systems Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Automatic sprinklers not required due to grandfather clause.	**101:13.3.5.1 [7]**	**X**		
	5000:16.3.5.1.1 [3]	**X**		
	IBC:903.2.1.2 [4]	**X**		
	101.12.3.5.1 [7]			X
Fire alarm system unable to alert people to hazard quickly enough to avoid trapping occupants in building.	IBC:907.2.1 [4]		X	
	5000:16.3.4 [3]		X	
Portable fire extinguishers ineffective/not used early in fire.	NFPA 10 [8]		X	

Table 8-3 Findings Concerning Occupant Load and Egress Relevant to Model Codes and Standards

Issue	References	Relev. H	M	L
Main entrance did not have capacity to handle 50% of the occupants on the night of the fire, and 50% would have been insufficient to safely evacuate all occupants in time (1-1/2 minutes).	**IBC:1024.2 [4]** **5000:16.2.3.3 [3]**	**X**		
Trained crowd managers not required for occupant loads < 1000.	**101:12.7.5 [7]** **101:13.7.5 [7]**		**X** **X**	
Festival seating increased the number of occupants permitted.	5000:16.2.5.4.1 [3] 101:12.2.5.4.1 [7] 101:13.2.5.4.1 [7] 5000:16.2.4.1 [3]		X X X X	
Higher occupant load factor permitted in IBC.	**IBC:1004.2 T [4]** **5000:11.3.1.2 T [3]**		**X** **X**	
Lower egress capacity factor permitted in IBC if sprinklers are installed.	**IBC:1005.1 T [4]** **5000:11.3.3.1 T [3]**		**X** **X**	
Location of alternative exits not obvious to patrons unfamiliar with nightclub, in spite of proper exit signs above doors.	IBC:16.4.7.5 [4] 5000:11.10.1.4 [3]		X X	
Longer common path of travel allowed in IBC.	IBC:1013.3 [4] 5000:16.2.5.1.2 [3]		X X	
Interior leaf of platform door did not swing in direction of egress.	IBC:1008.1.1 [4] 5000:11.2.1.4.2 [3]			X X
Stairs and landings at side exits may not have been at same level on both sides of doors.	IBC:1008.1.4 [4] 5000:11.2.1.3 [3]			X X
Main entrance double doors not equipped with panic hardware.	IBC:1008.1.9 [4] 5000:16.2.2.2.3 [3]			X X

Table 8-4 Findings Relevant to National Practices

Issue	References	Relev. H	M	L
Automatic sprinklers not required due to grandfather clause.	**IBC:903.2.1.2 [4]** **5000:16.3.5.1.1 [3]**	**X** **X**		
Polyurethane foam used as sound insulation on platform and walls.	**education, practice**	**X**		
Model codes can provide a meaningful level of safety only when adopted, practiced, and enforced by local jurisdictions.	**policy, practice**	**X**		
Model codes do not guarantee safety of occupants in all anticipated situations.	**policy**		**X**	
Criteria for optimum allocation of resources among routine inspections, prevention programs, and emergency response not established.	policy, practice, research		X	
Inspection reports not maintained.	**101:12.7.1 [7]** **101:13.7.1 [7]**		**X** **X**	
	IBC:104.7 [4] 5000:1.7.6.6.4 [3]			X X
Portable fire extinguishers ineffective/not used early in fire.	training, practice			X
Stairs and landings at side exits may not have been at same level on both sides of doors.	IBC:1008.1.4 [4] 5000:11.2.1.3 [3]			X X
Main entrance double doors not equipped with panic hardware.	IBC:1008.1.9 [4] 5000:16.2.2.2.3 [3]			X X
Details of work not included in permits, or permits not obtained.	IBC:105.1 [4] 5000:1.7.6.1.1 [3]			X X
No indication that building was inspected following completion of work.	IBC:109.1 [4] 5000:1.7.6.6.1.3 [3]			X X

8.3 RECOMMENDATIONS FOR IMPROVING MODEL STANDARDS, CODES AND PRACTICES

The findings presented above raise a number of issues concerning model codes and standards, and the practices surrounding their adoption, application, and enforcement. The process for modifying current model codes is laid out clearly by the NFPA and the ICC. The major standards developing organizations (ANSI, ASCE, ASME, ASTM, ISO, NFPA and UL) also have set procedures for amending the standards they maintain. The decision to adopt one or more sections of a model code is made at the local or state level. The federal government has no direct role in code adoption, but individual representatives of federal agencies can propose modifications to the model standards and codes, and can share their expertise with the private sector technical committees responsible for particular building and fire standards or sections of the model codes. NIST, as authorized by the NCST Act, is obligated to recommend modifications that are warranted by the findings of its investigations. Some significant

actions already have been taken by the state of Rhode Island and the NFPA that incorporate aspects of the recommendations that follow, and these actions are described in section 8.4.

8.3.1 Recommendations for all new and existing nightclubs

The first four recommendations should be applied in the model codes to all new and existing nightclubs regardless of size The application to all existing nightclubs is a recognition that (i) the environment within The Station became lethal in less than 1-1/2 minutes, and (ii) the control of building contents, finish materials, and occupancy limits has been demonstrated to be considerably less rigorous in nightclubs (see Appendix C for multiple examples) than in most other places of assembly.

Recommendation 1

The results of the investigation clearly demonstrated the value of an NFPA 13 compliant automatic fire sprinkler system in extending the time the nightclub remained tenable.

NIST recommends that model codes require sprinkler systems for all new and existing nightclubs regardless of size, and that state and local authorities adopt this provision.

Recommendation 2

The reaction to fire of building finish materials and contents is mentioned throughout the building and fire codes. The investigation identified portions of the national model codes and standards that were inadequate in this area.

In relation to the fire performance of finish materials and building contents, NIST recommends that model codes require, and that state and local authorities adopt the following provisions:

- ***a) certain classes of materials (including non-fire retarded flexible polyurethane foam) that are known to easily ignite and rapidly propagate flames (i.e., they have an ignition temperature below some minimum, or a flame spread index and heat release rate greater than some maximum values) be clearly and specifically forbidden, with no exceptions, as finish materials from all new and existing nightclubs;***
- ***b) greater guidance be provided for when large-scale tests are required to demonstrate that materials do not pose an undue hazard for the use intended;***
- ***c) the pass/fail criteria for flame spread tests and large-scale tests (including ASTM E-84, NFPA 255, and NFPA 286) be established using best measurement and prediction practices; and***
- ***d) strengthen provisions in NFPA 1126 (Use of Pyrotechnics before a Proximate Audience) which apply to all new and existing nightclubs through the following actions: banning the use of pyrotechnic devices from buildings less than 10,000 ft^2; requiring that all materials (including structural, finish, and contents) in structures that pyrotechnic devices are to be permitted meet low flame spread and heat release rate criteria; and require a minimum clearance greater than twice the designed projection of the pyrotechnic device from the nearest fixed surface or moveable contents.***

Recommendation 3

The rationale for changes in egress provisions include the realization that other fire safety systems may be non-functional; that the impact of smoke, heat, and gases on human behavior during evacuation is not

known; that mobility challenged persons take longer to evacuate; and that threats other than fire can require rapid evacuation.

NIST recommends that the factor of safety on the time for occupants to egress from all new and existing nightclubs be increased in the model codes in the following manner, and that state and local authorities adopt these provisions:

a) Compute the number of required exits and the permitted occupant loads assuming at least one exit (including the main entrance) will be inaccessible in an emergency evacuation.

b) Increase the capacity of the main entrance to accommodate, at a minimum, 2/3 of the maximum permitted occupant level during an emergency.

c) Eliminate trade-offs between sprinkler installation and factors that impact the time to evacuate buildings.

d) Require staff training and evacuation plans for buildings that cannot be evacuated in less than 1-1/2 minutes.

e) Provide improved means for occupants to locate emergency routes -- such as exit signs near the floor and floor lighting -- once standard exit signs become obscured by smoke.

f) Establish the threshold building area and occupant limits for egress provisions using best practices for estimating tenability and evacuation time.

g) Require explicit evacuation directions be provided to occupants prior to the start of any public event inside a structure used for public assembly.

Recommendation 4

A current practice that could have influenced the outcome of The Station fire was the use of the grandfather clause to exclude safety upgrades to existing buildings.

NIST recommends that model building and fire codes require, and that state and local authorities adopt, the application of new life-safety provisions to existing as well as new nightclubs, and that the practice of grandfathering of older structures be eliminated. Exemptions from the new provisions should be on a case-by-case basis and justified by a comprehensive fire safety analysis using best practices.

8.3.2 Recommendations for Improving General Building and Code Practices

The general public expects, and has a right to expect, that the model codes upon which their community depends will protect them from severe hazards in public buildings that can be anticipated. Invariably, the source of a building failure that leads to significant loss of life can be traced to a breakdown in one or more of the following key assumptions upon which the model codes are based: 1) the building designer, constructor, owner, operator, staff and patrons adhere to all applicable code provisions; 2) the historical record is a reliable predictor of worst case events; and 3) the authorities having jurisdiction (AHJ) properly interpret and enforce the code provisions. Building officials and the profession should strive for model codes that are robust and sensibly redundant to minimize the chances of loss of life caused by the failure of a building that is out compliance, or is operating out of compliance, with one or more code provisions. The next two recommendations, along with recommendation 4, are intended to move model codes and the building and fire safety professions in that direction.

Recommendation 5

NIST recommends that model codes and standards require redundancy in the passive and active fire protection systems to ensure adequate performance of the structure when one or more of the protective systems is compromised by uncertain behaviors of the building owner or occupants such as the following:

- ***a) installing building decorations or temporary features that greatly exceed flame spread or fire load provisions;***
- ***b) exposing the building to strong ignition sources;***
- ***c) exceeding the posted occupancy limits;***
- ***d) temporarily blocking an exit; and***
- ***e) disabling sprinklers or other life safety systems for maintenance.***

Recommendation 6

Appendix C recounts dozens of other tragedies in nightclubs and places of assembly where adherence to the model building and fire codes would have prevented the failure of the building. Of most relevance to the current incident are the Happy Land Social Club fire[17], the Gothenburg Dance Hall fire [18], the Café de Hemel fire [19], and the E2 Nightclub [20]. Each of these events killed between 14 and 87 people, with the root causes related to limitations on exits, overcrowding, an unanticipated initiating event, and (except for E2) building contents and materials that were inconsistent with the model fire codes.

NIST recommends that when performing an analysis of proposed changes to model building and fire codes, proper account should be taken of the soundness of and safety factor provided by the existing provisions in light of the history of similar building failures.

Recommendation 7

Portable fire extinguishers, if readily available, can be effective early in a fire and delay fire spread in the event the sprinkler system is not functioning.

NIST recommends that the model codes increase the number of portable fire extinguishers required, with their number and placement based upon a minimum time for access and application in a fully occupied building, and that staff be properly trained in their use.

8.3.3 Recommendations for fire prevention and emergency response

Even though the first fire engine arrived expeditiously, the speed at which the fire engulfed The Station rendered it impossible for the fire department to save the structure or the lives of many victims. However, the importance of the role of fire prevention activities in avoiding a future tragedy was highlighted by this incident. As in all mass causality events, especially those where the window of opportunity for rescue is extremely limited, effective and efficient communications within and among the various responding agencies is imperative. Developing effective interoperable communications requires addressing numerous critical success factors, including frequent use of interoperable communications equipment and procedures, formal governance and collaboration, formal standard operating procedures, appropriate technology, and multiagency training and exercises. Tools and best practice models addressing many of

these success factors, including a statewide communications interoperability planning methodology are available though the Department of Homeland Security's SAFECOM Program.

Recommendation 8

An effective fire prevention and inspection program can greatly enhance the ability of emergency service providers to protect their community.

NIST recommends that the model codes provide specific guidance on how to implement an effective fire inspection program, including the training necessary to implement it, and that state and local authorities adopt such guidance in practice. Items to consider include the following:

- ***a) documentation of building permits and alterations;***
- ***b) means of egress inspection and record keeping;***
- ***c) frequency and rigor of fire inspections, including follow-up and auditing procedures;***
- ***d) education and training of inspectors, owners and operators; and***
- ***e) guidelines on recourse available to the inspector for identified deviations from code provisions.***

Recommendation 9

An effective response to a structure fire/mass casualty incident is critically dependent upon sufficient staffing of the responding units and communications capabilities the IC will utilize to direct appropriate operations and tactics.

NIST recommends that

- ***a) career and volunteer fire departments comply with the minimum apparatus staffing such as suggested in NFPA Standards 1710 [5] and 1720 [13], respectively, and 1500 [14] as appropriate;***
- ***b) public safety agencies at all levels give greater attention to the difficulty of communications systems interoperability, and that fire service and emergency medical services organizations make every effort to assure they develop and maintain sufficiently robust, interoperable communications capabilities to support major incident operations, including those requiring substantial mutual aid augmentations, such as those suggested in NFPA Standard 1221; and***
- ***c) major incident/mass casualty operations be conducted utilizing appropriate Incident Command/ Unified Command structures, policies and practices such as suggested in NFPA Standard 1561 [16].***

8.4 ACTIONS ALREADY TAKEN

The magnitude of the incident at West Warwick invoked a swift response by code developing organizations as well as by the State of Rhode Island. A number of the most critical recommendations from NIST presented above already have been enacted, either on a temporary emergency basis or as a permanent change to the codes. Some NIST recommendations have been addressed only partially, while aspects of others have been proposed and rejected by code bodies. Table 8-5 provides a cross-walk between the recommendations from NIST and the actions already taken that are discussed below.

(i) National Fire Protection Association

The Standards Council of NFPA held hearings to consider Technical Interim Amendments (TIAs) to address certain life safety issues raised by The Station fire. The TIAs dealt with sprinklers, occupancy levels, crowd management, and means of egress. The following TIAs, and the NFPA Code section to which they apply, were approved in July 2003:

- Sprinkler existing nightclub type facilities and festival seating venues with occupant loads greater than 100 (TIA #739R, 101: 13.3.5.1 [7])
- Sprinkler new nightclub type facilities and festival seating venues (TIA #741R, 101:12.3.5.1 [7], and TIA #743R, 5000: 16.3.5.1.1 [3])
- Require trained crowed managers for existing and new assembly occupancies (TIA #738, 101:12.7.5 [7] and 101:13.7.5 [7])
- Restrict festival seating in new and existing facilities if occupant load is greater than 250 unless life-safety evaluation conducted (TIA #737R, 101:12.2.5.4.1 [7] and 101:13.2.5.4.1 [7]; and TIA #740R, 5000:16.2.5.4.1 [3]).
- Require of owner means of egress inspection and record keeping (TIA #742R, 101:12.7.1 [7] and 101:13.7.1 [7]).

(ii) International Code Council

A number of proposals for code changes related to The Station fire incident were submitted to the ICC at its September 2003 public hearing. One proposal, to require foam plastics covered with a textile or vinyl facing to pass a flame spread test (proposal FS108-03/04) [4], was approved.

Several proposals were aimed at increasing the capacity of the main entrance and the area requirement per occupant:

- Proposal E101-03/04 to eliminate 300 occupant minimum before requiring 50% capacity for main entrance, and increasing capacity requirement to 67%
- Proposals E102-03/04 and E103-03/04 to increase capacity of main entrance to 75% and 67%, respectively.
- Proposal E11-03/04 to increase area required per occupant from 0.47 m^2 (5 ft^2) to 0.65 m^2 (7 ft^2)
- Proposal E13-03/04 to eliminate sprinkler trade-offs with egress width requirement

These proposals were disapproved, primarily due to lack of technical justification to substantiate the change. The recommendations for research presented later in this chapter were made to address this issue.

Table 8-5. Actions taken by model code bodies and State of Rhode Island

NIST Recommendation	Related Action Taken	Comments
1. Strengthen requirement for sprinklers	NFPA TIA #739R NFPA TIA #743R	NIST recommendation based upon max egress time (1-1/2 minutes), NFPA mod based upon occupant load (100)
	RI strengthened regulation requiring sprinklers	based upon occupant load (150), some exemptions
2. Strengthen restrictions on foam plastic finish materials and use of pyrotechnics	ICC FS108-03/04	ICC action deals with one aspect of foam plastic finish materials; NIST recommendation is broader, needs formal proposal
	RI strengthened restrictions on pyrotechnics	same objectives as NIST recommendation, needs formal proposal
3. Increase factor of safety on egress	NFPA TIA #737R NFPA TIA #738	NIST recommendation is broader, based upon egress time rather than occupant load; some research required before formal proposal is submitted
4. Eliminate practice of grandfathering	adopted by RI	grandfathering not required by code; local and state jurisdictions can eliminate practice if so desired
5. Require redundancy in active and passive fire protection systems	none	formal proposal required
6. Include high consequence-low probability events on cost/benefit analyses	none	some research may be required before formal proposal can be submitted

NIST Recommendation	Related Action Taken	Comments
7. Increase number of fire extinguishers	RI increased number required in stage areas	formal proposal required
8. Enhance guidance for fire inspection programs	NFPA TIA #742R	NFPA action encompassed within broader NIST recommendation, needs formal proposal
	RI strengthened fire marshal's enforcement power	critical aspect of NIST recommendation
9. Adopt and practice communication, response, and command structures already established	no code modifications needed	more local and state jurisdictions should consider adopting and practicing guidance already in model codes and standards
10. Conduct research to understand human behavior better in emergency situations	none	multi-agency effort needed
11. Conduct research to understand fire spread and suppression better	none	work ongoing at NIST and elsewhere
12. Conduct research to refine computer-aided decision tools	none	work ongoing at NIST and elsewhere

(iii) State of Rhode Island

The State of Rhode Island acted quickly to examine its own building and fire codes. A special legislative commission was formed, held hearings, and delivered its report to the governor on June 5, 2003 [21]. Quoting from the letter of transmittal, five actions were identified to improve building standards, codes, and practices:

- "Require the use across the board of up-to-date fire safety codes -- this will require the elimination of the "grandfather clause"-- and the coordinated administration of fire safety building codes.
- Prohibit the use of pyrotechnics in places of assembly such as nightclubs and strictly regulate their use in large venues…that can accommodate them safely.
- Mandate sprinklers in nightclubs with an occupancy of 150 or greater and in all Class A and B places of assembly, except places of worship and state and municipal buildings used for government purposes and place other requirements on nightclubs as high risk places of assembly.
- Provide greater enforcement powers to fire marshals to assure their ability: a) to make inspections, b) to require immediate abatement of conditions that pose an imminent threat to public safety or property and when necessary to order a premises vacated, and c) to inspect of nightclubs and other places of assembly during their actual hours of operation.
- Establish comprehensive planning requirements to identify in the future the weaknesses in Rhode Island's approach to fire safety and to recommend actions needed to improve fire safety."

The Fire Safety Code of the State of Rhode Island was amended significantly by The Comprehensive Fire Safety Act of 2003 [22] to address these five items and other issues discussed in the June 5 Report. Among the most significant changes was the adoption by Rhode Island of the Uniform Fire Code (NFPA 1) [5] and the Life Safety Code (NFPA 101) [7], which now includes the provisions of TIAs #737R, 738R, 739R, 740R, 741R, 742R, and 743R. All new and existing places of assembly in Rhode Island with a capacity greater than 300 will be required to be completely protected by an approved automatic sprinkler as of July 1, 2005. For new and existing buildings similar to The Station nightclub with occupancy less than 301 but greater than 150, the deadline for installing sprinklers is July 1, 2006. Additional provisions in The Comprehensive Fire Safety Act of 2003 include the requirement for two 20 pound fire extinguishers in stage areas and the strengthening of inspection authority for the Fire Marshal.

8.5 RESEARCH RECOMMENDATIONS AND OTHER APPROPRIATE ACTIONS

This investigation focused on The Station nightclub. Several recommendations in this report relate directly to nightclub structures, and other recommendations apply more broadly. Model building code organizations as well as state and local regulatory authorities should review the results of this investigation and consider the findings regarding sprinklers, egress, and materials flammability as they make revisions to their codes.

The acceptance by the model code and standards organizations of the recommendations being made by NIST and the adoption of modified provisions of the national model codes into the local code depend upon the strength of the technical evidence when weighed against the economic impact of implementing

the change. There are a number of areas where the benefits may be obvious and the costs of implementation to the property owner and community can be computed easily. In those areas, to apply a particular provision of the code or not becomes a local policy decision that is not necessarily hindered by a lack of information available to the decision-maker.

There are other areas in which the basis for making the change is unsupported by data or technical rigor. Research is often needed in order to gain new knowledge and collect the data necessary to ensure that such changes are adopted if justified, or rejected if not. Research results also serve as the basis for setting thresholds or pass/fail criteria.

8.5.1 Recommendations for Research

NIST is required, under the NCST Act, to identify areas of research needed to support improvements to model building codes, standards and practices. Based upon the findings of this investigation and the resultant recommendations presented in section 8.3, additional research is recommended in three general areas:

- human behavior and people movement,
- material behavior and fire spread, and
- decision aids.

Recommendation 10

A basic tenet of our model codes is that public buildings should be designed and operated in a manner that assures there is enough time for occupants to evacuate safely for an anticipated worst case fire. In addition, we need to determine the desired behavior of occupants when faced with an unanticipated extreme event. Crowd-crush as observed in The Station fire also occurred in the E-2 [18] nightclub in Chicago the week prior to The Station incident, killing 21 people even though there was no fire, or even a real threat to the occupants. There is a need to understand better the behavior of people and crowds in emergency situations to pinpoint the factors that lead to crowd crush. This would enable sensible changes in building design to minimize the possibility of crowd crush, and improved ways to communicate to the crowd in emergency situations that go beyond the code.

NIST recommends that research be conducted to better understand human behavior in emergency situations, and to predict the impact of building design on safe egress in fires and other emergencies (real or perceived), including the following:

a) the impact of fire products (gases, heat, and obscuration) on occupant decisions and egress speeds;

b) exit number, placement, size and signage;

c) conditions leading to and mitigating crowd-crush;

d) the role of crowd managers and group interactions;

e) theoretical models of group behavior suitable for coupling to fire and smoke movement simulations; and

f) the level of safety that model codes afford occupants of buildings.

Recommendation 11

The behavior of people in a fire emergency and the time they have to escape depend upon the speed at which the fire spreads. Significant progress has been made in our ability to model the dynamics of a fire moving through a building, as evidenced by the simulations of The Station fire presented in this report. However, the state of the technology is insufficient to *accurately* model, in general, the spread of fire over common composite structures such as foam insulation on plywood, fabric covered foam furnishings, or gypsum covered wood frames. The detailed mechanisms for the formation of toxic products and smoke are extremely complex and are not amenable for inclusion in predictive fire models. Instead, it is necessary to rely on scientific experiments and real-scale fire testing of products and room geometries that are similar to what existed in the actual event to develop the empirical data required as input to computer fire models. This can be an impossible task for a fire that has occurred in a very large space, or when the fire totally destroys the structure along with the key evidence necessary for a reasonable recreation.

The time available for safe egress is influenced by the building geometry and ventilation system, the materials of construction and furnishings, and actions to suppress the fire. Predicting sprinkler activation and suppression and the influence of fire fighting activities on the spread of the fire is another aspect of the problem that cannot be done today to any but the grossest level of precision.

NIST recommends that research be conducted to understand fire spread and suppression better in order to provide the tools needed by the design profession to address recommendations 1 through 10, above. The following specific capabilities require research:

a) prediction of flame spread over actual wall, ceiling and floor lining materials, and room furnishings;

b) quantification of smoke and toxic gas production in realistic room fires; and

c) development of generalized models for fire suppression with fixed sprinklers and for firefighter hose streams.

Recommendation 12

New knowledge, data, and predictive methods generated in the above research will lead to new technologies and improved fire standards. The selection among alternative fire safety technologies or building design options, and the setting of threshold values in the model codes, can have significant economic ramifications. New tools are needed that can be tailored to the individual stakeholder that rigorously account for cost in a manner transparent to competing interests.

NIST recommends that research be conducted to:

a) refine computer-aided decision tools for determining the costs and benefits of alternative code changes and fire safety technologies, and

b) develop computer models to assist communities in allocating resources (money and staff) to ensure that their response to an emergency with a large number of casualties is effective.

8.5.2 Impact of Research

Completing the research recommended will put a sound technical foundation under the changes to codes, standards and practices that have already been made or are suggested. Specifically, a comprehensive research program would lead to an ability to:

- evaluate the impact of changing egress capacity and occupant load factors on the minimum time available for safe evacuation;
- quantify the value of increasing the size of the main entrance to handle a greater fraction of the occupant load;
- determine the relationship between flame spread rating on finish materials and fire spread in actual buildings;
- predict the smoke and toxic gas levels to a much greater level of precision, and the ramification of these fire products on occupant movement;
- quantify the value of sprinklers in places of assembly with different occupant loads, and compare the performance of alternative designs;
- investigate different strategies for managing crowds under various threat types and levels;
- supplement training for firefighters, fire marshals, other emergency responders, code officials, and crowd managers; and
- educate building owners, their employees and the general public on approaches to remain safe in places of assembly.

8.6 REFERENCES FOR CHAPTER 8

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[2] *Providence Journal*, "In the Fire," p. B4, February 20, 2004.

[3] *NFPA 5000, Building Construction and Safety Code*, National Fire Protection Association, Quincy, MA, 2002

[4] *2003 International Building Code*, International Code Council, Inc., Country Club Hills, IL, 2002.

[5] *NFPA 1710, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Career Fire Departments*, National Fire Protection Association, Quincy, MA, 2001.

[6] *NFPA 1, Uniform Fire Code*, National Fire Protection Association, Quincy, MA, 2003.

[7] *NFPA 101, Life Safety Code*, National Fire Protection Association, Quincy, MA, 2003.

[8] *NFPA 10, Standard for Portable Fire Extinguishers*, National Fire Protection Association, Quincy, MA, 2002

[9] *ASTM E84-00a, Standard Test Method for Surface Burning Characteristics of Building Materials*, American Society for Testing & Materials, West Conshohocken, PA, 2001.

[10] *NFPA 286, Standard Methods of fire Tests for Evaluating Contribution of Wall and Ceiling Interior Finish to Room Fire Growth*, National Fire Protection Association, Quincy, MA, 2002.

[11] *NFPA 255, Standard Method of Test of Surface Burning Characteristics of Building Materials*, National Fire Protection Association, Quincy, MA, 2002.

[12] *NFPA 1126, Use of Pyrotechnics before a Proximate Audience,* National Fire Protection Association, Quincy, MA, 2002

[13] *NFPA 1720, Standard for the Organization and Deployment of Fire Suppression Operations, Emergency Medical Operations, and Special Operations to the Public by Volunteer Fire Departments,* National Fire Protection Association, Quincy, MA, 2001.

[14] *NFPA 1500, Standard on Fire Department Occupational Safety and Health Program,* National Fire Protection Association, Quincy, MA, 2002.

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[20] Johnson, Mark, *Chicago Club had been told to Close*, Milwaukee Journal Sentinel, 18 Feb. 2003.

[21] "Making Rhode Island the Safest State," Report to the Rhode Island General Assembly, June 5 2003.

[22] Comprehensive Fire Safety Act of 2003, Chapter 23-28, Amendment to the General Laws, Health and Safety, SECTION 2. Title 23.